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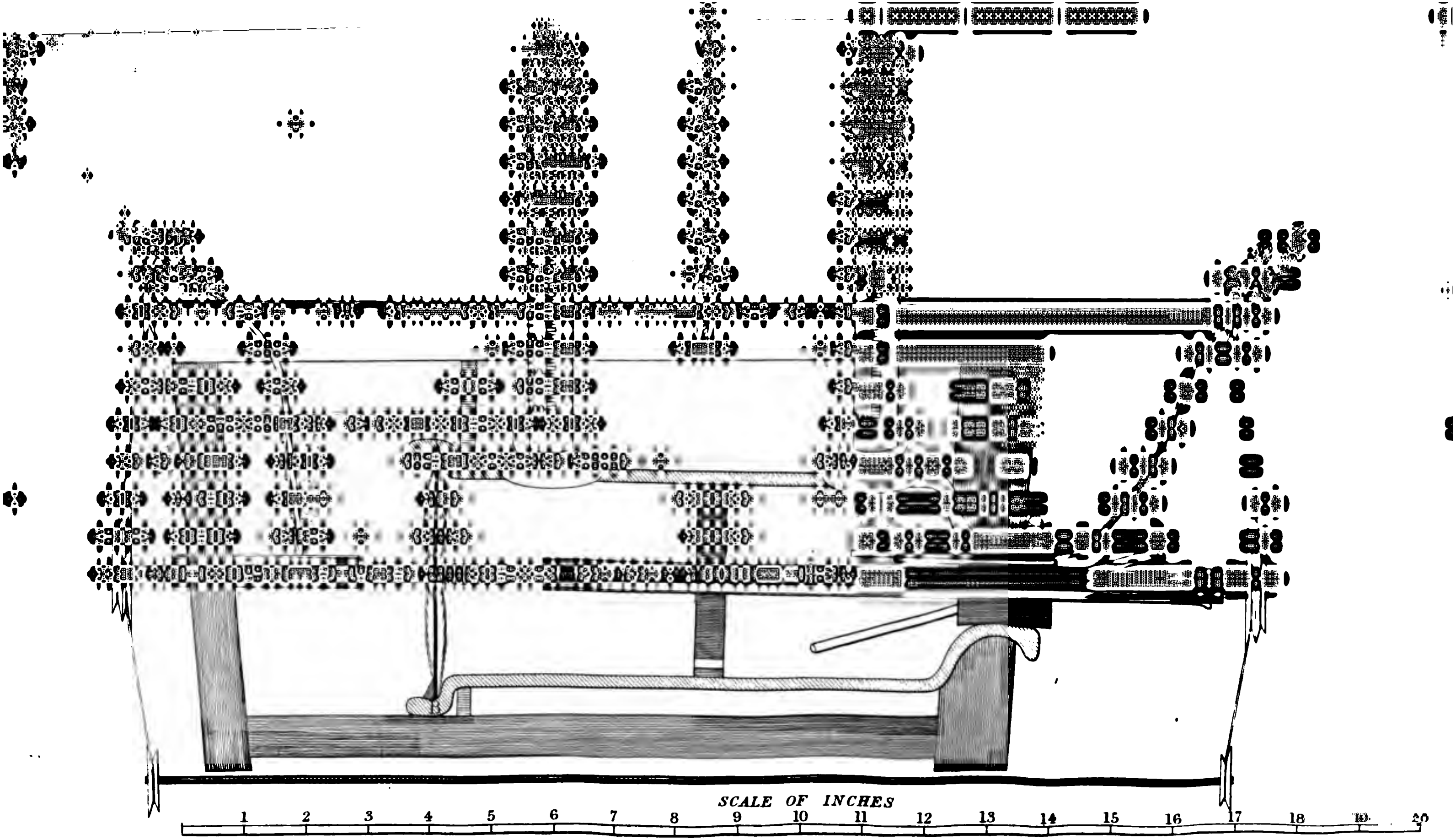

SCALE OF INCHES

NOTES OF EXPERIMENTS,

WITH

THOUGHTS ON ELECTRICITY.

BY

CHARLES CHALMERS,
MERCHISTON.

EDINBURGH: SUTHERLAND & KNOX, GEORGE STREET.
LONDON: SIMPKIN, MARSHALL, & CO.

MDCCCL.

1973.

negative wire, are given off in combination with the negative electricity of that wire ; and therefore, when a compound body is decomposed by electricity, we do not obtain the constituents of that body, but new compounds, the two electricities having respectively combined with the constituents of the body which has been decomposed. Thus in the decomposition of potassa by electricity, we do not obtain the constituents of that body, but new compounds—one of the constituents of potassa having combined with positive electricity, oxygen being the product; the other constituent of potassa having combined with negative electricity, potassium being the product ; and in order to obtain the constituents of potassa, we would require to disunite positive electricity from oxygen, and negative electricity from potassium. In the decomposition of a neutral salt by electricity, we do not obtain the constituents of that body, but new compounds. One of the constituents of the salt having combined with positive electricity, a compound is formed possessing properties different from either of the constituents, an acid being the product : the other constituent of the salt having combined with negative electricity, a compound is formed possessing properties different from either of the constituents, an alkali being the product ; and in order to obtain the constituents of the salt which has been decomposed, we would require to disunite positive electricity from the acid, and negative electricity from the alkali. According to these views, the following facts and experiments are, I think, intelligible.

2. When an acid and an alkali are brought into contact with each other, how is it that great heat is

evolved, and a compound is formed possessing neither the properties of an acid nor an alkali?

The acid, in combining with the alkali, gives off its positive electricity, and is thus deprived of that which imparted to it the properties of an acid; and the alkali, in combining with the acid, gives off its negative electricity, and is thus deprived of that which imparted to it alkaline properties; and because of this, a compound is formed by the combination of the ponderable constituents of the acid and alkali, possessing neither alkaline properties nor the properties of an acid, and the great heat evolved is consequent upon the union of the two electricities which are given off.

3. If an acid and alkali give off their respective electricities when they combine, and form a neutral salt, what is the cause of this?

Is it that the two electricities, when brought into proximity, have a greater affinity for each other than they have for the ponderable elements with which they are combined; and because of this, when a compound body is under electro-decomposition, if the wires from the battery are made to touch each other, the compound body ceases to be decomposed? The two electricities which are now brought into close proximity, combine with each other rather than with the constituents of the body which is under decomposition; and therefore, when an acid and an alkali are brought into intimate contact, atom to atom, the positive electricity of the acid and the negative electricity of the alkali being thus in close proximity, combine, heat being the product.

4. If a platinum capsule, which contains a solution

of caustic potash, be connected with one wire of an electrometer, and a slip of platinum connected with the other wire is dipped into nitric acid, and introduced into the potash, how is it that the capsule in contact with the alkali indicates the presence of negative electricity, and that the slip of platinum in contact with the acid indicates the presence of positive electricity ?

The acid, in combining with the alkali, gives off its positive electricity, and the alkali, in combining with the acid, gives off its negative electricity ; and therefore, the slip of platinum in contact with the acid indicates the presence of positive, and the platinum capsule in contact with the alkali, the presence of negative electricity.

5. When an acid decomposes a neutral salt by combining with the alkaline base of the salt, how is it that the combination gives rise to no heat, as in the former example (2), and the acid base which is set free has its acid properties restored ?

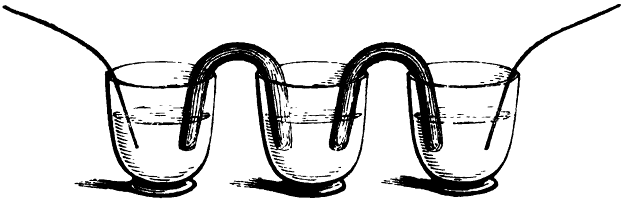
The acid which decomposes the neutral salt, in combining with the alkaline base of the salt, gives off its positive electricity to the base of the acid which is liberated, and because of this the acid base which has been set free has its acid properties restored ; and no heat is evolved, because, in the new combination, the union of the two electricities does not take place, (2). The positive electricity of the acid which has decomposed the neutral salt, has united with the acid base which has been set free ; and the alkaline base of the salt has no electricity to give off, having previously parted with its negative electricity in its first combination to form a neutral salt.

6. When an alkali decomposes a neutral salt, by combining with the acid base of the salt, how is it that this new combination gives rise to no heat, as in example (2), and that the alkaline base which is liberated has its acid properties restored ?

The alkali which decomposes a neutral salt gives off to the alkaline base which is liberated its negative electricity, and because of this the alkaline base which has been set free has its alkaline properties restored ; and no heat is evolved, as in example (2), because in the new combination the union of the two electricities does not take place. The alkali in the decomposition of the neutral salt gave off its negative electricity to the alkaline base which has been set free, and the acid base with which it combined to form the neutral salt had no positive electricity to give off, having previously parted with its positive electricity in its first combination to form a neutral salt.

7. In double decompositions, as in the case of two neutral salts when they decompose one another, in which the acid base of the one combines with the alkaline base of the other respectively, how is it that these combinations give rise to no heat (2), and no current of electricity (4) ?

When an acid and an alkali enter into combination and form a neutral salt, they give off their respective electricities, heat being the product ; and therefore in double decompositions, when the two neutral salts decompose one another, and enter into new combinations, the constituents of these salts have no electricity to give off, and because of this they give rise to no heat and no current of electricity.



8. When three cups, N, I, and P, are arranged as represented in the woodcut, and the negative wire from a battery is introduced into cup N, and the positive wire into P—the three cups being connected by means of amianthus—how is it that a solution of a neutral salt when put into I, and distilled water into the cups N and P, the neutral salt is decomposed, and in every instance the ponderable constituent of the acid is decanted into P, and the alkaline constituent into N ?

The ponderable constituent of the acid in the solution of the neutral salt is attracted to the positive wire in the cup P, and there combining with positive electricity, resumes the properties of the acid; and the ponderable constituent of the alkali is attracted to the negative wire in the cup N, and there combining with negative electricity, resumes its alkaline properties.

9. When N is filled with a solution of the sulphate of potash, and the cups I and P with distilled water, the water in I being tinged with a solution of litmus, how is it that in the decomposition of the sulphate of potash, the acid base of the salt is transferred to cup P, but in passing through the intermediate cup I, the solution of litmus is not reddened ?

The constituents of a neutral salt possess neither the properties of an acid nor those of an alkali; when, therefore, the sulphate of potash is decomposed, the acid base of the salt has not yet acquired the properties of an acid—it has not yet combined with positive electricity; it therefore passes through the solution of litmus in the intermediate cup I, without changing its blue colour into red; and is decanted into cup P, where it combines with positive electricity, and has its acid properties restored. If the contents of the cup P be now poured into the intermediate cup I, the colour of the litmus will be reddened.

10. When the cup P is filled with a solution of the sulphate of potash, and the cups N and I with distilled water—the water in I being tinged with turmeric—how is it that in the decomposition of the sulphate of potash, the alkaline base of the salt, in passing through the intermediate cup I on its route to N, does not change the colour of the turmeric?

In the decomposition of the salt the alkaline base does not possess alkaline properties—it has not yet combined with negative electricity—it therefore does not change the colour of the turmeric in its passage through I. When, however, it reaches the cup N, it there combines with negative electricity, and has its alkaline properties restored. If the contents of the cup N be now decanted into I, the colour of the turmeric will undergo the characteristic change.

11. When the cup I is filled with a weak solution of ammonia, the cup N with a solution of the sulphate of potash, and distilled water is put in the cup P, the sulphate of potash is decomposed; the acid base of the salt being set free, is attracted by the

positive wire to the cup P, but in its passage through I it produces no chemical change upon the solution there—a combination does not take place between the ammonia and the acid base which passes through it. How is this?

The sulphate of potash in the cup N is decomposed, and the acid base of the salt is set free, and is attracted towards the cup P; but in passing through the intermediate cup, it does not combine with the ammonia and form a neutral salt, because the alkali in I requires to give off its negative electricity before its ponderable constituent can combine with the ponderable constituent of the acid. The constituent of the alkali has a greater affinity for its imponderable element than it has for the acid base which passes through it. There is therefore no chemical change produced upon the solution of ammonia in the cup I. When, however, the acid constituent of the sulphate of potash reaches the cup P, it there combines with positive electricity, and has its acid properties restored. If the solution in P which is now a solution of sulphuric acid, be decanted into I, the acid and alkali now combine—the positive electricity of the acid unites with the negative electricity of the alkali, heat being the product; and the ponderable elements of acid and alkali unite and form a neutral salt, namely, the sulphate of ammonia.

12. When a solution of the nitrate of potash is placed in the cup P, distilled water in N, and sulphuric acid in I, the alkaline constituent of the salt is drawn through the cup I without undergoing any change itself, or causing any change in the acid. What is the reason of this?

The alkaline constituent of the salt when it enters the cup I, containing sulphuric acid, does not combine with that acid. The sulphuric acid requires to be disunited from its positive electricity before it can combine with the alkaline base of the salt. When, however, the alkaline base passes to cup N, it there unites with negative electricity, and has its alkaline properties restored. If the alkaline solution in N be poured into the cup I, the positive electricity of the sulphuric acid will unite with the negative electricity of the alkali, heat being the product, and the base of the acid and the base of the salt will now unite and form a neutral salt.

13. When a solution of the sulphate of potash is put into the cup N, distilled water in P, and a solution of baryta in I, the sulphate of potash is decomposed, and the base of the acid, one of the constituents of the salt, is attracted by the wire in P, and is liberated; but the base of the acid does not pass through the solution of baryta as it passed through the solution of ammonia (11), but combines with the base of baryta, and is precipitated. How is this?

The base of baryta has the greatest affinity for the base of sulphuric acid, insomuch that it separates the base of that acid from all the alkalies and alkaline earths with which it combines, namely, strontia, potassa, soda, lime, magnesia, and ammonia. To account, therefore, for the precipitate in I, the base of baryta having a greater affinity for the base of sulphuric acid than it has for the negative electricity with which it is united, the baryta is decomposed, the negative electricity is set free, and the base of the acid is arrested in the intermediate cup I, by combining with the base of baryta, and because of this a precipitate of the sulphate of baryta takes place.

14. If the two electricities respectively combine with the other elements of nature and form compounds possessing properties different from those of their constituents—if, for example, in the decomposition of potassa by electricity, positive electricity combines with one of the constituents, and oxygen is the product, and negative electricity combines with the other constituent, and potassium is the product—then it is most desirable that a method could be found by which to disunite positive electricity from oxygen, and negative electricity from potassium, and thus obtain separately the constituents of potassa as they exist in that body, possessing neither the properties of oxygen nor those of potassium. As ammonia, the oxide of chlorine, and also the oxide of mercury, silver, and gold, are decomposed by heat, I imagined it possible that positive electricity might be disunited from oxygen, and negative electricity from potassium by heat also, and that I might thus obtain the residual constituents of these bodies, possessing neither the properties of oxygen nor those of potassium.

With this view I employed a cast-iron tray, (fig. A,) twelve inches in length, ten inches in width, and three inches and a half in depth. Into this tray I put, to the depth of one inch, a mixture of plaster of Paris, and finely sifted coal-ash, and upon the surface of this mixture I placed two thick glass-tubes, hermetically sealed, the one containing a portion of the chlorate of potassa, and the other an equivalent quantity of potassium. These tubes

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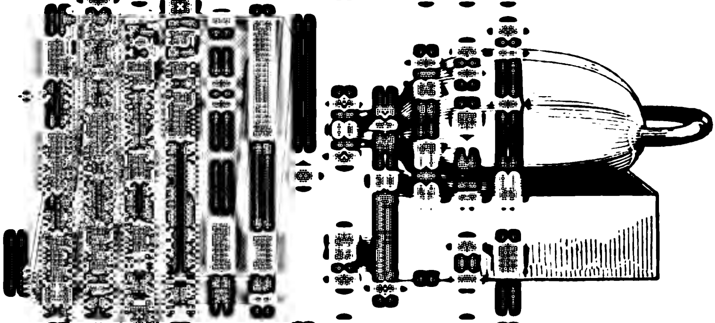

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The result of this experiment was as follows :—The tubes which contained the potassium burst into fragments ; but as the explosion did not take place until the tray had been exposed to a strong heat for upwards of an hour and a half, I inferred that any change which had occurred in the nitric acid contained in the tubes that remained entire, must have taken place before the explosion of the tubes which contained the potassium. I found that the colour of the nitric acid contained in the tube with the platina-wire was changed, from being colourless it had become of a bright yellow, but that the colour of the acid in the other tube had undergone no change. How is this ? Was it that one equivalent of positive electricity had been withdrawn from the nitric acid by the platina-wire, and had combined with one equivalent of negative electricity, which had been given off by the potassium in the other tube, and because of this the acid was changed from nitric to nitrous acid ? or had the nitric acid, consequent upon an exposure to strong heat, given off one equivalent of its oxygen, and therefore the nitric acid become nitrous acid ? If this was the cause of the change in the colour, how was it that the same change of colour did not occur in the other tube, which was exposed precisely to the same temperature ?

These experiments are not decisive, but they are certainly not discouraging. Hitherto I have operated with tubes of flint-glass, which are not suitable. Could I obtain, what I find is most difficult to procure, thick green glass-tubes, then I am prepared to undertake a series of experiments, which I feel assured would be decisive either one way or another.

HYDROGEN OBTAINED FROM WATER WITHOUT OXYGEN.*

THE vessel in which the gases are evolved is a glass-jar, which is laid upon its side in a wooden trough. The trough is divided into two compartments by a partition, which is water-tight. One of the compartments is filled with water, and the other into which the body of the jar is laid, is empty. The bottom of the jar, which projects beyond the partition of the trough, consists of a circular plate of platina, A B, about five inches in diameter, the margin of which is imbedded in white paint, covered over with a cement of bees'-wax, resin, and finely powdered brick-dust, and is thus rendered perfectly tight. The neck of the jar, which is of considerable width, for the purpose of admitting a large cork, is fixed into one end of the trough. The upper part of the vessel has two tubulures, into which are inserted the tubes for collecting the respective gases. These tubes are graduated into centesimal parts of a cubic inch. A diaphragm of cork divides the glass vessel into two cells, to prevent the gas which is given off in one cell from passing into the other. The diaphragm is covered on both sides with sealing-wax which had been dissolved in alcohol. At the lower part of the diaphragm an opening is made, which is stuffed with moist cotton, to prevent any interruption to the current of electricity that would otherwise take place. Into the neck of the jar a large cork is fitted. Through the centre of this cork passes a spindle, by the turning of which a wiper, consisting of four radiating arms, is made to sweep the platina-plate of any bubbles of gas which might adhere to it. This spindle is a glass-rod, and is encased through nearly its whole length in a glass-tube, which fits accurately an aperture in the centre of the diaphragm, and that in the cork at the neck of the jar. The ends of this tube are made tight by two corks, through which the spindle passes. The other surface of the platina-plate has also the bubbles of air which might adhere to it swept off by a similar apparatus—the spindle of which passes through the opposite end of the trough. By means of a series of pulleys and spindles, represented in the engraving, the wipers, if I may so call them, are made to revolve and to press against the respective surfaces of the platina-plate. The whole system of pulleys and spindles was connected with a steam-engine, from which I borrowed a small portion of its power. The negative wire of the battery was introduced into the glass-jar, and the positive wire into the compartment of the trough filled with water. Both the water in the jar and the water in the trough were slightly acidulated. With these arrangements I proceeded with my experiments.

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* For description of the apparatus by which the experiment is performed,—see Engraving opposite title-page.

It is evident that gas would come off from both wires of the battery, just as if no platina-plate had been interposed—platina being a conductor of electricity, and that by induction the two sides of the platina-plate would possess opposite electrical states. It is also obvious, that whatever quantity of electricity might be accumulated at the extremity of either wire, an equivalent quantity of the opposite electricity would by induction be diffused over the surface of the plate presented to that wire; and as oxygen and hydrogen are not given off from the wires of a battery, when the electricity is low in intensity and small in quantity, I inferred that when the power of the battery was so very low, that the gases were but sparingly given off from the respective wires, that the induced electricity of the plate, by virtue of its distribution over so large a surface, would be so attenuated, so low in intensity, and so small in quantity at any one point of that surface, that neither oxygen nor hydrogen would come off from either surface of the plate; and, therefore, when hydrogen was coming off from the wire in the glass-jar, oxygen would not be given off from the surface of the plate presented to that wire, and thus hydrogen might be obtained from water without oxygen.

For the first experiment twelve cells of the battery were put in connexion, and with every successive experiment the number of cells was diminished until oxygen had ceased to come off from the platina-plate. Every experiment was repeated first with the wipers unemployed, and second, with the wipers employed, and with a very striking difference in the result.

EXPERIMENT FIRST.

TWELVE CELLS OF BATTERY IN CONNEXION.

First.	*Second.*
Wipers unemployed.	Wipers employed.
Result.	*Result.*
100 cent. parts of hyd. from wire.	100 cent. parts of hyd. from wire.
44 cent. parts of ox. from plate.	33 cent. parts of ox. from plate.
ox. *minus* 6 cent. parts.	ox. *minus* 17 cent. parts.

EXPERIMENT SECOND.

TEN CELLS OF BATTERY IN CONNEXION.

First.	*Second.*
Wipers unemployed.	Wipers employed.
Result.	*Result.*
100 cent. parts of hyd. from wire.	100 cent. parts of hyd. from wire.
41 cent. parts of ox. from plate.	21 cent. parts of ox. from plate.
ox. *minus* 9 cent. parts.	ox. *minus* 29 cent. parts.

EXPERIMENT THIRD.

EIGHT CELLS OF BATTERY IN CONNEXION.

First.	*Second.*
Wipers unemployed.	Wipers employed.
Result.	*Result.*
100 cent. parts of hyd. from wire.	100 cent. parts of hyd. from wire.
37 cent. parts of ox. from plate.	14 cent. parts of ox. from plate.
ox. *minus* 13 cent. parts.	ox. *minus* 36 cent. parts.

EXPERIMENT FOURTH.

SIX CELLS OF BATTERY IN CONNEXION.

First.	*Second.*
Wipers unemployed.	Wipers employed.
Result.	*Result.*
100 cent. parts of hyd. from wire.	100 cent. parts of hyd. from wire.
32 cent. parts of ox. from plate.	10 cent. parts of ox. from plate.
ox. *minus* 18 cent. parts.	ox. *minus* 40 cent. parts.

EXPERIMENT FIFTH.

FIVE CELLS OF BATTERY IN CONNEXION.

First.	*Second.*
Wipers unemployed.	Wipers employed.
Result.	*Result.*
100 cent. parts of hyd. from wire.	100 cent. parts of hyd. from wire.
22 cent. parts of ox. from plate.	3 cent. parts of ox. from plate.
ox. *minus* 28 cent. parts.	ox. *minus* 47 cent. parts.

EXPERIMENT SIXTH.

FOUR CELLS OF BATTERY IN CONNEXION.

First.	*Second.*
Wipers unemployed.	Wipers employed.
Result.	*Result.*
100 cent. parts of hyd. from wire.	100 cent. parts of hyd. from wire.
3 cent. parts of ox. from plate.	ox. from plate, *none.*
ox. *minus* 47 cent. parts.	

The wipers were now constantly employed with four cells of battery in connexion.

EXPERIMENT SEVENTH.

90 cent. parts of hyd. from wire ; ox. from plate, *none.*

EXPERIMENT EIGHTH.

90 cent. parts of hyd. from wire ; ox. from plate, *none.*

EXPERIMENT NINTH.

80 cent. parts of hyd. from wire ; ox. from plate, *none.*

EXPERIMENT TENTH.

100 cent. parts of hyd. from wire ; ox. from plate, *none.*

EXPERIMENT ELEVENTH.

96 cent. parts of hyd. from wire ; ox. from plate, *none.*

EXPERIMENT TWELFTH.

100 cent. parts of hyd. from wire ; ox. from plate, *none.*

The wipers now gave way, and the experiments were discontinued. The gas which came off from the negative wire in the glass-jar, and which was collected in the graduated tube, was tested from time to time in the usual way, and was found to be pure hydrogen. I have since obtained hydrogen from water without oxygen, with the wipers removed from the platina-plate. The wipers, I find, can be dispensed with. For the last two months hydrogen has come off from the platina-wire in the jar at the rate of twelve centesimal parts in the twenty-four hours, but oxygen has not been given off from the platina-plate.

If water is a binary compound, of which one of the elements is hydrogen and the other oxygen, the difficulty is to account for the absence of oxygen in these experiments. It cannot have disappeared by forming with water a peroxide of hydrogen; for the peroxide of hydrogen is decomposed by the Voltaic battery. It is also decomposed at a temperature of 50° and upwards. Now the water in the jar was kept up to a temperature above 70°, in consequence of its proximity to a steam-engine, which was almost constantly at work. It is also rapidly decomposed by introducing into the water the oxide of silver. This was done, and no gas was evolved, the water having been previously deprived of the acid which it contained by a solution of baryta. How then came it that hydrogen was obtained from water without oxygen?

Is water so far as we yet know an elementary body? Does it combine with positive electricity, and is oxygen the product? Does it combine with negative electricity, and is hydrogen the product?

Are oxygen and hydrogen, therefore, compound bodies; oxygen formed by the union of water with positive electricity—hydrogen formed by the union of water with negative electricity? And when these two gases are mixed together in their equivalent proportions, and raised to a given temperature, are they decomposed? Does the positive electricity of the oxygen combine with the negative electricity of the hydrogen, heat being the product? and is the water which was in combination with the respective electricities given off?

SMEE'S MECHANICAL PRINCIPLE

APPLIED TO THE COMMON ZINC AND COPPER BATTERY AS ALSO TO THE CONSTANT BATTERY OF PROFESSOR DANIELL.

WITH a view to the application of Smee's Mechanical Principle to the common zinc and copper battery, I have employed cylinders of copper, perforated by means of a sharp-pointed instrument of five sides. Each puncture made by this instrument presents a projecting edge of five serratures, and each serrature has a ragged edge of minuter serratures. With upwards of three thousand punctures to each cylinder of copper, and with numerous points projecting from the ragged edge of each puncture, I find from experiment that I have obtained for the common zinc and copper battery the full benefit of Smee's Mechanical Principle.

The form of battery which I have adopted is much the same as that devised and described by Mr. Thomas Mason in the *Annals of Electricity*, vol. iii. p. 13, with this difference—I use zinc-rods in place of cylindrical vessels of zinc, *punctured* in place of plain sheets of copper, and for connecting the cells into pairs, I have adopted cleft plates of brass, supported upon stout copper-wires, instead of brass-cups, to

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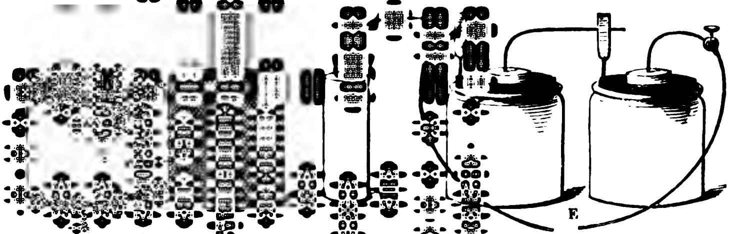

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